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Application of TOPSIS in Prioritization of Safety Training to Minimize Accidents in a Thermal Power Station

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Abstract – *Training is considered as an essential facet of occupational health and safety courses and it is conveyed with the resolution of increasing the knowledge, skill and capability of the worker. As, an amateur worker is himself the ultimate hazard for any functioning industry The research performed in this paper seeks to determine the training topic which should be frequently covered on the basis of the past accidents data using descriptive analysis. The research attempts to use TOPSIS Fuzzy logic to identify the contractual company having past history of accidents and to propose suitable training program in order to avoid any accidents in the near future.*

Key Words*: *Safety Training, TOPSIS, Prioritization Training

1.INTRODUCTION

India is only second to China in terms of workforce. The latest available data (Figure 1.1) shows that in the year 2020 India had around 500 million workers out of which the Indian industrial sector consist of nearly 26.18% of the total workers in India. Also, India is appending nearly 13 million fresh workers every year to its workforce.

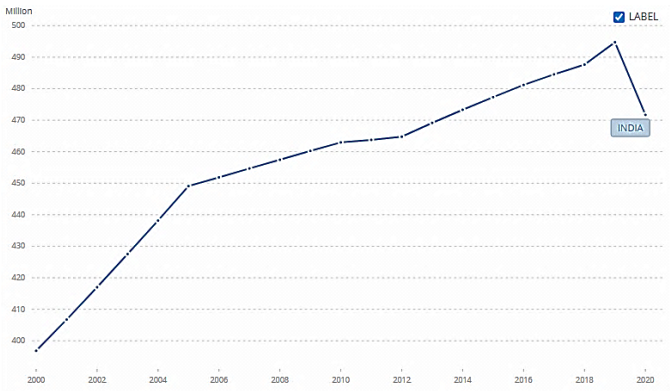

Figure 1 Total Labour force in India (Source: https://data.worldbank.org/)

A report by Human Development 2020, states that "only one in five labour in India is skilled" [1] ranking India at 129th among 162 countries other countries. The present state of workers and the skill they possess can be estimated by this report.

Training and development emerged in response to national crisis in the early 20th Century with the rise of training societies and associations with more emphasis on dramatic training approaches. Heavy incursion of fresh and unskilled workers to meet the industrial demands during the World Wars necessitated the need of basic work specific training to the workers. As most of the workers for war during the World Wars, heavy demand of on-site instructors and supervisors emerged to train the new workforce. Job Instruction Training (JIT) was used to tutor the defense industry supervisor for instructing the new labours in acquiring the skills required for the job.

In the late 1970s, technological advancements took place in the training community with the use of computers, videotapes and satellites. During 1980-90 computers started to become an essential part of trade and industry, hence most the companies started providing basic essential training to operate a computer to the workers. This initiated the concept of computer-based training method which we still use to impart skills and knowledge to the workers.

OHS training denotes to strategic efforts to expedite the learning of OHS explicit competencies. [2] Now, Training denotes to a strategic effort by a enterprise to expedite learning of job-related competencies, skills, knowledge, and behaviours by workers. The objective of training is for workforces to conquer the knowledge, skills, competencies, and behaviours stressed in training and administer them to their day-to-day chores. Conventionally, enterprises have mostly depended on formal training carried with a course, program, or "event" to impart workforces the knowledge, skills, and behaviours they require to effectively perform their task. [2]

With the global expansion of different enterprises and ever changing technologies, Indian industries have formed a system that has crafted workforce as a pedigree of advantage which gives the optimum results in the competitive market. The cutting-edge technological development has created awareness & demand and has understood the prominence of safety training in Indian industries. Nowadays, workers are no longer willing to connect with any new company where their skills and knowledge do not get upgraded with time.

The objective of this research is to prioritize the companies working in the construction of a thermal power plant in order to provide effective training to the company whose past record is poor.

2. LITERATURE REVIEW

Lippin et al., (2000) [10] in his research assessed the impact of hazardous material training program based on empowerment let by two union-led on the health & safety

of a workplace across four industrial sectors. The methodology adopted by the author involves telephonically performed interview survey with 362 workforces and their superiors, 6-12 months following training. The trainees testified improved attempts and accomplishments in supporting the occupational health and safety changes along with individual changes in cognizance and work culture. The research concluded that the adopted approach is effective in development workers' capability to initiate amendment in the workplace.

Colligan et al., (2004) [11] inspected the part of training in encouraging employee safety and health from three perspectives. The first perspective involves dealing with the principled and circumstantial matters linked with the workplace safety training. The second perspective encompasses an assessment of the research works to assess the effectiveness of training as a health & safety intervention. The objective behind this is to determine the critical constituents of effective training interventions with an eye toward hands-on recommendations. To end with, the third perspective tries to deliver some supervision for forthcoming research and program development linked to occupational safety and health training.

The research led by Robson et al.,(2012) [12] determines the impact of occupational health and safety training on the workers and also scrutinizes whether longer and enhanced safety training engagements has a larger effect than lesser safety training engagements. The authors reviewed journal database of 11 years and identified 22 studies meeting the set criteria for pre and post randomized experimental studies focusing on variety of working professionals, hazards and training types with the objective of preventing occupational injuries and accidents. Using the standardized mean difference approach, the impact of safety training was summarized by the author. The effectiveness of training was assessed on the basis of three critical parameters:

- Attitude and Belief
- Behaviour
- Health

The research concluded that the OHS training provided to workers had a strong positive impact on the working practices of workers but the research was unable to find the impact of effectiveness of training on the health of workers.

The earlier works of Burke et al. (2006) [13] point out that training methodology concerning safety has significant implications for the efficacy of training in terms of knowledge and performance of the trainee.

But, Robson et al. (2010) [14] reviewed 16 experimental studies and reasoned the claims by Burke et al. (2006) [13] on the attainment of greater impact on health and safety upon higher training engagements.

Later, Burke et al. (2011) [15] justified the statement "highly engaging training was considerably more effective than less engaging training when hazardous event/exposure severity was high, whereas highly and less engaging training had comparable levels of effectiveness when hazardous event/exposure severity was low" by bringing the concept of dread factor which influences the worker and creates a sense of realization of injury vulnerability. According to the author this experienced feelings or affect plays a key role in motivating persons to study about how to evade exposure to ominous hazards.

The research work by Burke et al., (2011) [15] discusses about the socially constructed perception of risk and presented three hypothesis in relation to the comparative effectiveness of diverse methods of safety training. The variables under investigations were

- Hazardous events
- Safety training methods

The author stated that the interaction of these variables affects the knowledge attainment and occupational safety behaviour of the worker. The authors systematically and analytically investigated using few hypotheses that the impact of safety training and occupational hazards on the improvement of safety knowledge and safety routine. The author concluded that "For safety knowledge and safety performance, highly engaging training was considerably more effective than less engaging training when hazardous event/exposure severity was high, whereas highly and less engaging training had comparable levels of effectiveness when hazardous event/exposure severity was low."

Many research outcomes support the idea of sense of fear/hostile feeling being the encouraging factor for acting in a way to lessen the fear or sensation by acquiring proper knowledge and training in our case. [16]–[20]

In order to develop and deliver effective workplace safety training Wilkins (2011) [21] investigated the workers' conception and perception of safety training by using both qualitative and quantitative type questionnaires. Data from 121 construction professionals were collected after a rigorous ten-hour safety training course. The study reveals that trainees are more prospective to retort positively to training programmes when fully developed learning theories are incorporated into safety trainer readiness programmes.

O'Connor et al., (2014) [22] analysed the indispensable essentials of effective occupational safety and health training programs with special focus on underserved communities. The author provides a path for the management and safety practitioners to the vital factors for designing and implementing training programs for underserved communities and especially including the illiterate and Limited-English-speaking workers.

3. METHODOLOGY

To know more about the safety and training, site visit was shepherded at an under construction Thermal Power Station with a planned capacity of 1980 MW (3x660 MW). The construction site of the 1st unit of Thermal Power Station with a proposed capacity of 660 MW was subjected to study.

The objectives behind the visit were:

- To observe and note the safety training schedules
- To understand the procedure of training topic selection.
- To learn and observe about the training delivery modes.
- To take feedbacks from the trainees on the training.
- To understand the impact of safety training on the employees.
- To assess the interconnection between training and accidents

(a)

(b)

(c)

Figure 2 Safety Professionals delivering Tool Box Talk

3.1 Training Statistics

3.1.1 Details of training provided in the year 2020

Figure 3 lists out the specifics of induction training provided to the inductees upon new arrival or upon change the in job or task assigned during the year 2020. Due to the COVID-19 breakout in the month of March 2020, training and other activities were ceased and later upon re-commencement of work, special attention was laid on the training to prevent the spread of COVID-19 amongst the workers according to the protocols of state and central government.

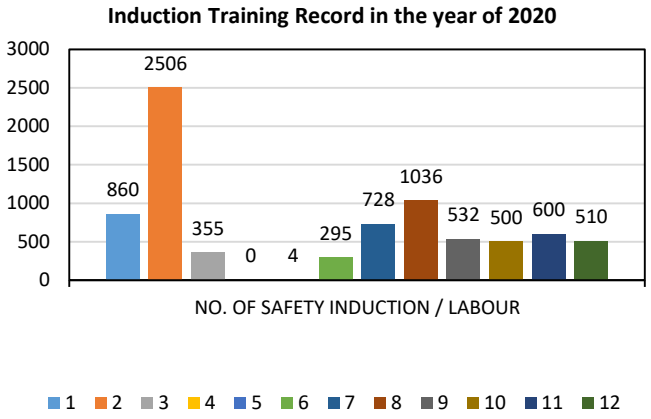

Figure 3 Chart showing the details of Induction Training Record in the year 2020

N: No of Participants; D: Duration; Hrs: Total training hours

Table 1 Detail of training conducted in the year 2020

S.No	Date	Topic	N	D	Hrs
1	04-03-2020	Fire	19	2	38
2	05-03-2020	Fire	23	2	46
3	06-03-2020	Work At Height	15	2	30
4	07-03-2020	Fire	43	2	86
5	18-03-2020	Covid-19	24	1	24
6	20-03-2020	Hot Work	22	2	44
7	24-06-2020	General Safety Awareness	15	2	30
8	24-06-2020	General Safety Awareness	15	2	30
9	29-06-2020	General Safety Awareness	24	2	48
10	29-06-2020	General Safety Awareness	24	2	48
11	30-06-2020	General Safety Awareness	18	2	36
12	02-07-2020	General Safety Training	33	2	66
13	03-07-2020	General Safety Training	9	2	18
14	04-07-2020	General Safety Training	32	2	64
15	07-07-2020	General Safety Training	12	2	24
16	08-07-2020	General Safety Training	53	2	106
17	13-07-2020	Safe Rigging & Lifting	19	2	38
18	16-07-2020	Safe Rigging & Lifting	6	2	12
19	21-07-2020	Height Work	57	2	114
20	22-07-2020	General Safety Training	18	2	36
21	29-07-2020	Height Work	32	2	64
22	30-07-2020	Height Work	15	2	30
23	30-07-2020	Safe Rigging & Lifting	13	2	26
24	31-07-2020	Height Work	13	2	26
25	31-07-2020	Electrical Safety	16	2	32
26	01-08-2020	Work At Height	32	2	64

27	04-08-2020	Fire Safety & Fire Fighting	11	2	22
28	05-08-2020	Induction Training	15	2	30
29	06-08-2020	Safe Rigging & Lifting	53	2	106
30	07-08-2020	Height Work	24	2	48
31	10-08-2020	Fire Prevention & Control	29	2	58
32	10-08-2020	Safe Rigging & Lifting	8	2	16
33	11-08-2020	Height Work	93	2	186
34	12-08-2020	Confined Space	26	2	52
35	13-08-2020	Safe Rigging & Lifting	12	2	24
36	14-08-2020	Height Work	25	2	50
37	14-08-2020	Hot Work	8	2	16
38	14-08-2020	Safe Rigging & Lifting	11	2	22
39	17-08-2020	Basic Scaffolding Training	37	2	74
40	18-08-2020	Scaffolding Safety	14	2	28
41	18-08-2020	Safe Rigging & Lifting	15	2	30
42	18-08-2020	Height Work	30	2	60
43	19-08-2020	Confined Space	18	2	36
44	19-08-2020	Confined Space	18	2	36
45	20-08-2020	Safe Rigging & Lifting	51	2	102
46	21-08-2020	Work At Height	34	2	68
47	22-08-2020	Electrical Safety	29	2	58
48	24-08-2020	Basic Scaffolding Training	19	2	38
49	25-08-2020	Work At Height	11	2	22
50	25-08-2020	Safety Working At Height	34	2	68
51	26-08-2020	Safety Working At Height	32	2	64
52	27-08-2020	Rigging & Lifting	21	2	42
53	27-08-2020	Safe Rigging & Lifting	21	2	42
54	03-09-2020	Work At Height	32	2	64
55	03-09-2020	Safe Working Height	32	2	64
56	04-09-2020	Work At Height	35	2	70
57	04-09-2020	Work At Height	36	2	72
58	04-09-2020	Safe Working Height	36	2	72
59	09-09-2020	Safe Working Height	40	2	80
60	10-09-2020	Confined Space	14	2	28
61	11-09-2020	Safe Working Height	30	2	60
62	11-09-2020	Driving Safety	12	2	24
63	14-09-2020	Scaffolding	17	2	34
64	15-09-2020	Confined Space	51	2	102
65	15-09-2020	Scaffolding	17	2	34
66	24-09-2020	Electrical Safety	17	2	34

Table provides the insightful details of training provided to workers with training topic, delivery date, count of trainees and training hours. The chart presented in Figure 3 clearly shows the training topics that were attended by most of the trainees along with the respective training hours. Upon slight observation it can be clearly pointed out that few training topics were given more emphasis as compared to the rest and these emphasized training topics were also attended by most of the workers involved in the construction. The identified topics are:

- Working at height
- Working in confined spaces
- Tackling Fire
- Safe rigging and lifting
- General safety training

Upon investigation it was found out that the training topic and training hours allotted were hand-picked on the basis of the past incidents, probable risk and probable level of hazard associated with operations.

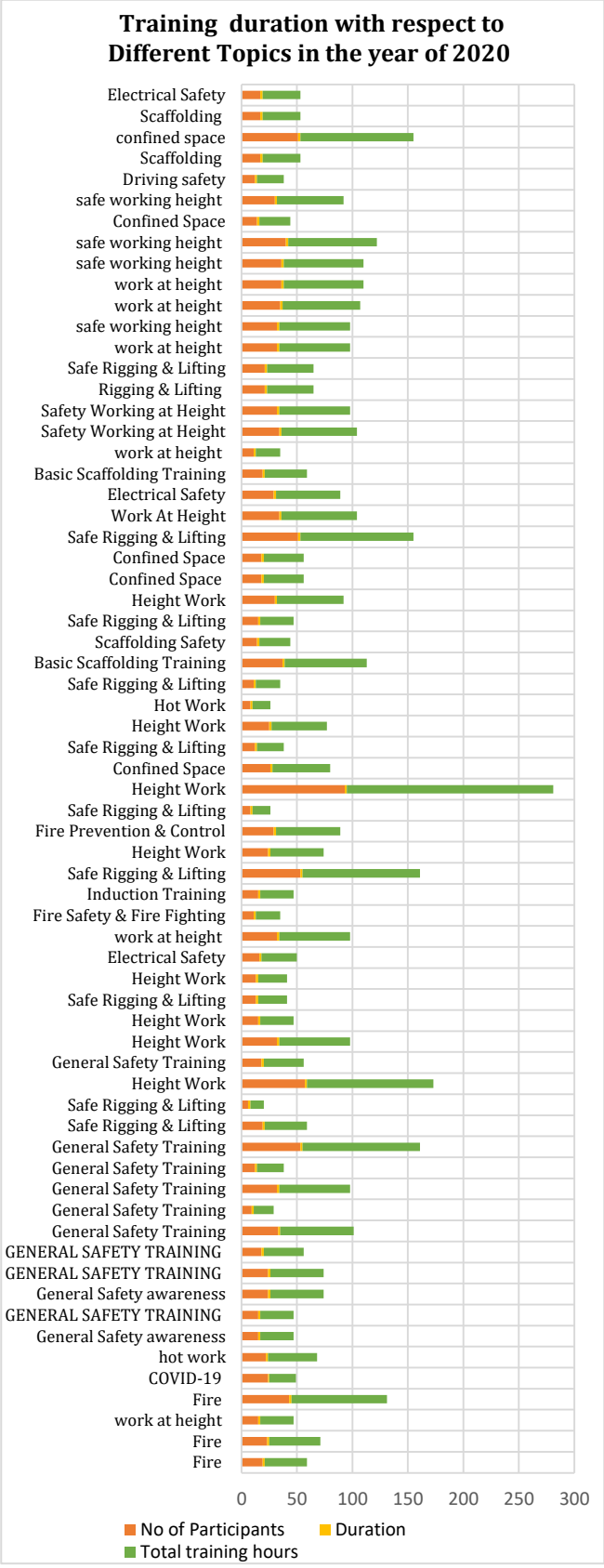

Figure 4 Training duration with respect to Different Topics in The year of 2020

Owing to the extent and diverse nature of construction, many companies are engaged for the proper management of different construction process. The details of training topic, delivery mode, participant count and training hours are displayed in Table 2. In order to avoid any public disclosure and to maintain the confidentiality of company details, the name of all the companies were substituted with a numeral series.

Table 2 Detail of training detail with respect to companies

Type	Topic	Company	N	D	Hrs
Class Room	General Safety Training		33	2	66
Class Room	General Safety Training		9	2	18
Class Room	General Safety Training		32	2	64
Class Room	General Safety Training		12	2	24
Class Room	General Safety Training		53	2	106
Class Room	Safe Rigging & Lifting	Company 1, Company 10, Company 23	19	3	57
ON JOB	Safe Rigging & Lifting	Company 5	6	2	12
Class Room	Height Work Training		57	2	114
Class Room	General Safety Training		18	2	36
Class Room	Height Work Training		32	2	64
Class Room	Height Work Training		15	2	30
Class Room	Safe Rigging & Lifting	Company 1	13	3	39
Class Room	Height Work Training		13	2	26
ON JOB	Height Work Training	Company 20	16	0.5	8
ON JOB	Fire Safety & Fire Fighting	Company 20	11	0.5	5.5
Class Room	Safe Rigging & Lifting	Company 1, Company 23, Company 5, Company 16	53	3	159
Class Room	Height Work Training		24	2	48
Class Room	Fire Prevention & Control	Company 1, Company 23, Company 10	29	2	58
ON JOB	Safe Rigging & Lifting	Company 3	8	2	16
Class Room	Height Work Training	Company 1, Company 23, Company 10	93	2	186
Class Room	Confined Space	Company 10, Company 31, Company 1, Company 23, Company 24	26	2	52
Class Room	Safe Rigging & Lifting	Company 1, Company 3	12	3	36
Class Room	Height Work Training	Company 23, Company 10, Company 1, Company 4	25	2	50
ON JOB	Hot Work Training	Company 4	8	0.5	4
ON JOB	Safe Rigging & Lifting	Company 1, Company 5, Company 10	11	1	11
Class Room	Scaffolding Training	Company 6, Company 25, Company 16, Company 24, Company 30, Company 10, Company 1, Company 20, Company 26	37	3	111
ON JOB	Scaffolding Training	Company 10	14	1	14
ON JOB	Safe Rigging & Lifting	Company 14	15	2	30
Class Room	Height Work Training	Company 23, Company 10, Company 1	30	2	60
Class Room	Confined Space Training	Company 1, Company 25, Company 14, Company 26	18	2	36
Class Room	Safe Rigging & Lifting	Company 1, Company 23, Company 14, Company 6, Company 16, Company 25, Company 5	51	3	153
Class Room	Height Work Training	Company 1, Company 28	34	2	68
Class Room	Electrical Safety Training	Company 25, Company 26, Company 3, Company 4, Company 30, Company 1, Company 14, Company 13	29	3	87
Class Room	Scaffolding Training	Company 6, Company 16, Company 23, Company 1, Company 25, Company 30, Company 29, Company 2, Company 4	19	3	57
Class Room	Safety Working at Height	Company 12, Company 1, Company 29	34	2	68
Class Room	Safety Working at Height	Company 6, Company 30, Company 28	32	2	64
Class Room	Safe Rigging & Lifting	Company 27, Company 20, Company 1	21	3	63
Class Room	safe working at height	Company 23,	32	2	64
Class Room	safe working at height	Company 14,Company 6,Company 1	36	2	72
Class Room	safe working at height	Company 30,Company 29,Company 10,Company 4,Company 1	40	2	80
Class Room	Confined Space Training	Company 24-Isg, Company 23 , Company 2,Company 1	14	2	28
Class Room	safe working at height	Company 4,Company 12,Company 1,	30	2	60
Class Room	Driving safety Training	Company 10,Company 4,Company 3	12	2	24
Class Room	Scaffolding Training	Company 23,Company 1,Company 6,Company 30,Company 2,	17	2	34
Class Room	Confined Space Training	Company 4,Company 27,Company 1	53	2	106
Class Room	Scaffolding Training	Company 23,Company 24, Company 1,Company 30,Company 2,Company 6	14	2	28

Type	Topic	Company	N	D	Hrs
Class Room	Scaffolding Training	Company 1,Company 2,Company 14,Company 25,Company 3,Company 14,	12	2	24
Class Room	safe working at height	Company 14	16	2	32
Class Room	Scaffolding Training	Company 10,Company 1,Company 3,Company 2,Company 14,Company 23,Company 16,Chola-Ms	26	4	104
Class Room	Safe working at height	Company 20,Company 14,Company 28.Company 2,	30	2	60
Class Room	safe working at height	Company 1,Company 15,Company 10	37	2	74
Class Room	Electrical Safety Training	Company 10,Company 18,Company 16,Company 1	17	2	34
Class Room	safe working at height	Company 1,Company 10,Company 23,Company 20	52	2	104
Total Training Hour					3028.5

Table 2 list outs the companies involved in the safety training process in the year 2020. The table also provides the details of training topic, delivery mode, count of trainees and training hours.

Figure 4 shows the details of training atmosphere opted for providing training to the workers, it can be clearly inferred that a lot more emphasis was given to the class room training as compared to the on-site training.

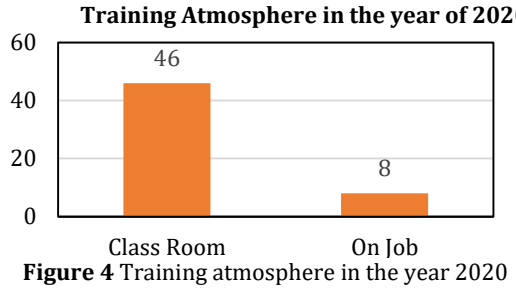

Figure 4 Training atmosphere in the year 2020

3.1.2 Details of Training provided in the year 2019

Table 3 shows the month-wise detail of safety induction training provided to the labours in the year 2019. The data clearly shows the consistency in induction training process throughout the year which is the outcome of the efforts, commitment and resolution of the health and safety training department.

Table 3 Detail of induction training in the year 2019

S.No	Year	Month	No. of Safety Induction
1	2019	April	1126
2	2019	May	1113
3	2019	June	1023
4	2019	July	1118
5	2019	August	1030
6	2019	September	1030
7	2019	October	953
8	2019	November	1155
9	2019	December	1204
10	2020	January	860
11	2020	February	2506
12	2020	March	355

Figure 5 represents the data from Table 3 in form of a chart to give a better understanding of the pattern of induction training in for each month in the year 2019.

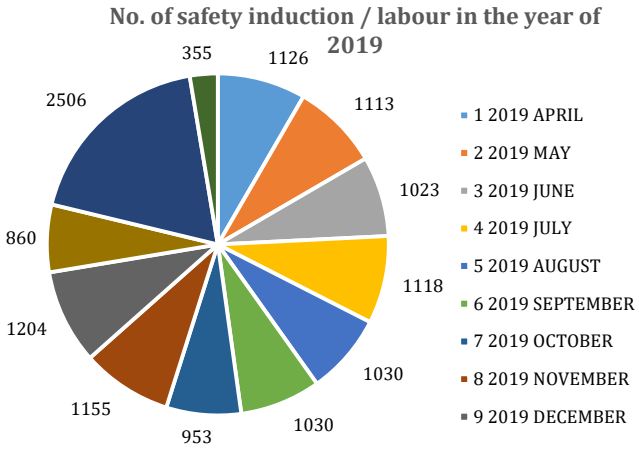

Figure 5. No. of safety induction / labour in the year of 2019

The data in Figure 6 gives out the training details conducted in the year 2019 which includes the training topic, training date, participants count and count of companies participated in the training process. It can be clearly seen from the data shown in Figure 6, that only general safety training was provided to the workers and no operation or task specific safety training was provided to the labours and workers in the year 2019. Also, only two days of general safety training was delivered throughout the year without any participation from the companies involved in the construction process.

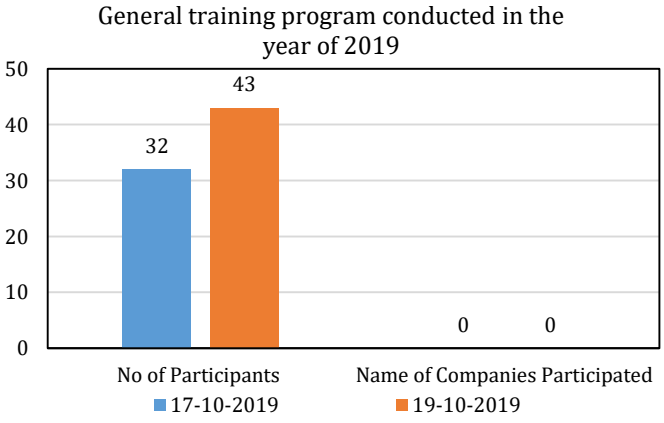

Figure 6. Details of participants and companies participating in general safety training program in 2019

3.1.3 Details of incidents, accidents and near-misses from year 2017 to 2020

Figure 7 shows the number of fire incidents reported by different companies in the year 2017, 2018, 2019 and 2020. Upon evaluation of data, it can be observed that M/S Company 3 reported the maximum number of fire incidents during the aforesaid durations. Moreover, M/S Company 1 also reported significant number of fire incidents whereas the rest of the companies reported the same number of fire incidents.

Figure 7. Details of Fire incident reported by companies between 2017 and 2020

Figure 8. Details of minor accidents recorded by companies between 2017 and 2020.

Figure 8 lays out the number of minor accidents reported by the companies in the 2017, 2018, 2019 and 2020. Upon slight observation, it can be clearly deduced from the data that, M/S Company 3 reported the maximum number of minor accidents in the aforesaid duration. Apart from M/S Company3, M/S Company1 and M/S Company 10 also have significant contribution to data of minor accidents.

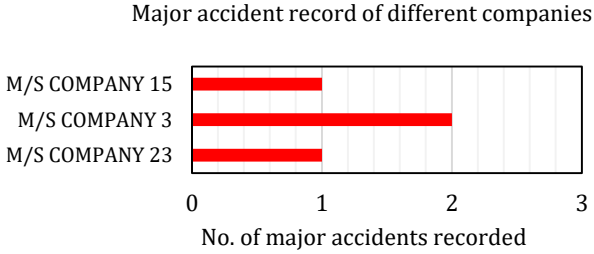

Figure 9. Details of major accidents recorded by companies between 2017 and 2020

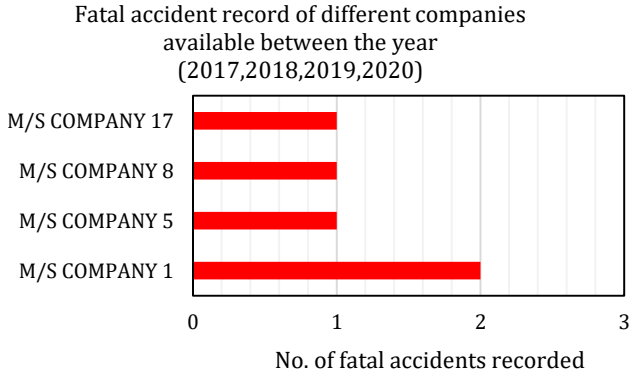

Figure 10. Details of fatal accidents recorded by companies between 2017 and 2020

Figure 9 and Figure 10 shows the details of major accidents and fatal accidents reported by the companies during the year 2017, 2018, 2019 and 2020. The data from Figure 9 clearly shows that M/S Company 3 contributed highly to the data of major accidents in the aforesaid duration and only two other company's M/S Company 15 and M/S Company 23 have reported the major accidents. Another important record which is vital for the analysis of workplace safety is the number of fatalities which can be deduced from Figure 10.

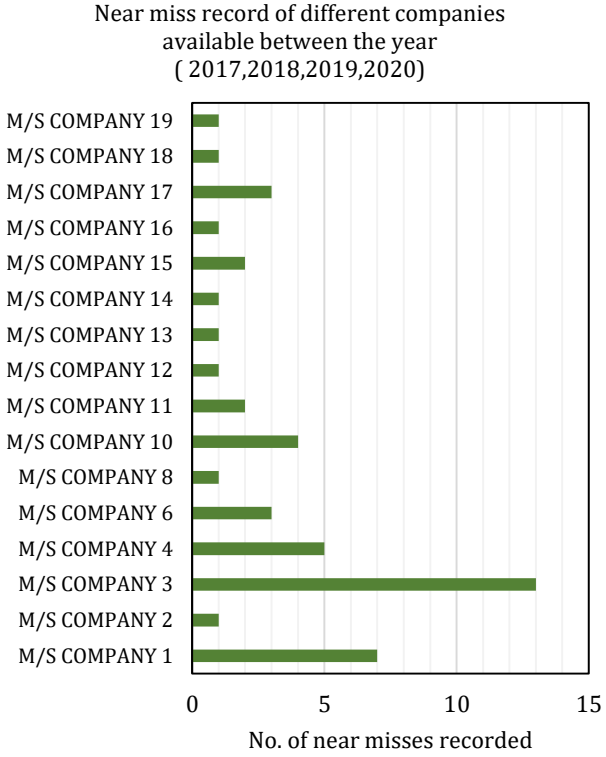

Figure 11 Details of near misses recorded by companies between 2017 and 2020

Figure 11 shows the details of near-misses recorded by different companies during the year 2017, 2018, 2019 and 2020. On observing the data, it can be concluded that M/S Company 3, M/S Company 1 and M/S Company 4 were the highest contributors in the database of near-misses

3.2 TOPSIS

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method (MCDA) which was developed by two researchers Hwang & Yoon, (1981). TOPSIS was further modified and improved by Yoon, (1987) and Hwang et al., (1993). This MCDA works on the primary concept of assortment of alternative next to the ideal and farthest away from the negative.

Here, the Ideal alternative is the best suitable Attribute which may be maximum or minimum. depending. on. the. type. of criteria Whereas, Negative ideal alternative is the worst attribute value which can also be maximum or minimum depending on the type of criteria.

The conventional technique of TOPSIS is to pick out single positive ideal solution (PIS) and single negative ideal. solution. (NIS). of. the. problem, compute. the. distance. from. respectively. substitute. to. PIS. and. NIS, then. equate. the. ratio. standards. of. the. second. distance. to. the. sum. of. the. two. remoteness. and. develops. the. final. ranking. of. the. options.

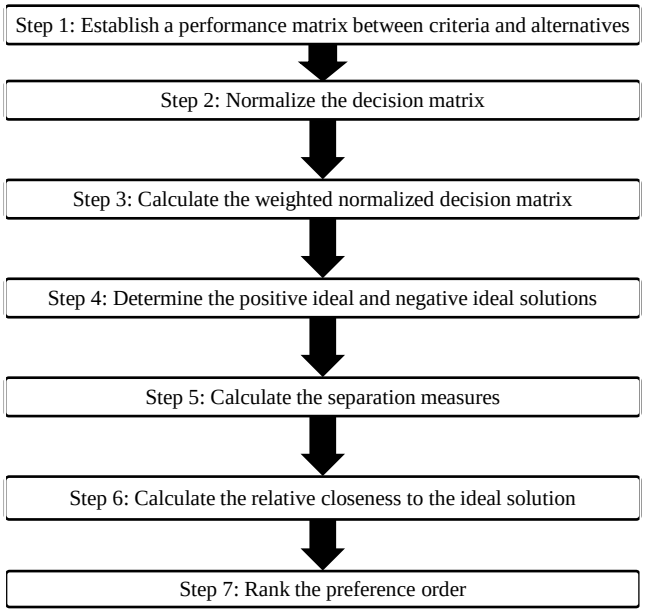

Figure 12 TOPSIS process flow chart

Step 1: Establish a performance matrix

The performance value of the alternatives is denoted by zij with respect to some attribute(A) / criterion (C);

$$M = \begin{matrix} & w_1 & w_2 & \cdots & w_n \\ & C_1 & C_2 & \cdots & C_n \end{matrix} \begin{pmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{pmatrix} \begin{pmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{pmatrix} \quad \text{Eq.(1)}$$

Step 2: Normalize the decision matrix

The following transformation equation can be used to obtain the normalized performance matrix.

$$n_{ij} = \frac{z_{ij}}{\sqrt{\sum_{j=1}^{m} (z_{ij})^2}} \quad \text{Eq.(2)}$$

j= 1,……,n, i=1,……,m.

Step 3: Calculate the weighted normalized decision matrix

Since the weights of criteria in problem have different mean and importance. Therefore, the normalized value is computed as:

$$v_{ij} = w_j \times n_{ij} \quad \text{Eq.(3)}$$

The weight is computed by direct assignation by the author on the basis of the field experience.

Step 4: Determine the positive ideal and negative ideal solutions

The positive ideal and the negative ideal value set 'A' are computed as follows:

$$A^+ = \{v_1^+, \ldots, v_n^+\} = \left\{ \left(\max_i v_{ij}, \ j \in J \right) \left(\min_i v_{ij}, \ j \in J' \right) \right\} \quad i = 1, 2, \ldots, m \quad \text{Eq.(4)}$$

$$A^- = \{v_1^-, \ldots, v_n^-\} = \left\{ \left(\min_i v_{ij}, \ j \in J \right) \left(\max_i v_{ij}, \ j \in J' \right) \right\} \quad i = 1, 2, \ldots, m \quad \text{Eq.(5)}$$

In the above equation, J is linked with benefit criteria, and J' is linked with Non-benefit criteria.

Step 5: Calculate the separation measures

The distance of each alternative from the positive ideal solution (PIS) A+ is:

$$d_i^+ = \left\{ \sum_{j=1}^{n} \left(v_{ij} - v_j^+ \right)^2 \right\}^{\frac{1}{2}}, \quad i = 1, \ldots, m \quad \text{Eq.(6)}$$

The distance of each alternative from the negative ideal solution (NIS) A- is:

$$d_i^- = \left\{ \sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2 \right\}^{\frac{1}{2}}, \quad i = 1, \ldots, m \quad \text{Eq.(7)}$$

Step 6: Calculate the relative closeness to the ideal solution

The relative closeness "R", to the ideal solution can be expressed as:

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, \ldots, m \quad \text{Eq.(8)}$$

$$\text{If } \bar{R}_i = 1 \rightarrow A_i = \bar{A}^+$$

$$\text{If } \bar{R}_i = 0 \rightarrow A_i = \bar{A}^-$$

The closer the Ri is to 1, the higher the will be the priority.

Step 7: Rank the preference order

Rank the suitable alternative in decreasing order on the basis of R_i

4. RESULTS

Based on the data of near-miss, Fire incidents, Minor accident, major accident and fatal accidents of the past four years (2017-2020) recorded and reported by the 23 companies under review, the ranking of companies on the basis of training requirement is necessary. The details of near-miss, Fire incidents, Minor accident, major accident and fatal accidents for the 23 companies are listed in Table 4.

The next task is to categorized the criteria between beneficiary and non-beneficiary criteria. As lower count of near-miss, Fire incidents, Minor accident, major accident and fatal accidents is desirable, hence they come under Non-beneficiary criteria

Furthermore, the next step involves the assignment of proper weightage is assigned to near-miss, Fire incidents, Minor accident, major accident and fatal accidents.

Table 4. Details of near-miss, Fire incidents, Minor accident, major accident and fatal accidents for all the companies

Alternative	Company	Near Miss	Fire Incident	Minor Accident	Major Accident	Fatal Accidents
		Cr-01	Cr-02	Cr-03	Cr-04	Cr-05
Alternative -01	M/S COMPANY 1	7	3	8	0	2
Alternative -02	M/S COMPANY 2	1	0	1	0	0
Alternative -03	M/S COMPANY 3	13	6	14	2	0
Alternative -04	M/S COMPANY 4	5	0	2	0	0
Alternative -05	M/S COMPANY 5	0	0	2	0	1
Alternative -06	M/S COMPANY 6	3	0	1	0	0
Alternative -07	M/S COMPANY 7	0	0	1	0	0
Alternative -08	M/S COMPANY 8	1	0	1	0	1
Alternative -09	M/S COMPANY 9	0	0	0	0	0
Alternative -10	M/S COMPANY 10	4	1	8	0	0
Alternative -11	M/S COMPANY 11	2	1	2	0	0
Alternative -12	M/S COMPANY 12	1	0	0	0	0
Alternative -13	M/S COMPANY 13	1	0	0	0	0
Alternative -14	M/S COMPANY 14	1	2	0	0	0
Alternative -15	M/S COMPANY 15	2	0	0	1	0
Alternative -16	M/S COMPANY 16	1	0	0	0	0
Alternative -17	M/S COMPANY 17	3	0	0	0	1
Alternative -18	M/S COMPANY 18	1	0	0	0	0
Alternative -19	M/S COMPANY 19	1	0	0	0	0
Alternative -20	M/S COMPANY 20	0	1	1	0	0
Alternative -21	M/S COMPANY 21	0	1	0	0	0
Alternative -22	M/S COMPANY 22	0	1	0	0	0
Alternative -23	M/S COMPANY 23	0	0	0	1	0
	TOTAL	47	16	41	4	5

Table 5 Allocated value of weightage to the criteria

Criteria	Near Miss	Fire Incident	Minor Accident	Major Accident	Fatal Accidents
	Cr-01	Cr-02	Cr-03	Cr-04	Cr-05
Weight in decimal	0.1	0.15	0.2	0.25	0.3
Weight in percentage	10%	15%	20%	25%	30%

The next step involves computation of Normalize the decision matrix using Eq.(2). Table 6 below shows the Normalize the decision matrix computed using the values obtained in Table 5

Table 6 Normalized decision matrix

S No.	Near Miss	Fire Incident	Minor Accident	Major Accident	Fatal Accidents
Alternative -01	2.8626106	1.2247449	3.4657943	0.0000000	1.5118579
Alternative -02	0.0584206	0.0000000	0.0541530	0.0000000	0.0000000
Alternative -03	9.8730854	4.8989795	10.6139951	1.6329932	0.0000000
Alternative -04	1.4605156	0.0000000	0.2166121	0.0000000	0.0000000
Alternative -05	0.0000000	0.0000000	0.2166121	0.0000000	0.3779645
Alternative -06	0.5257856	0.0000000	0.0541530	0.0000000	0.0000000
Alternative -07	0.0000000	0.0000000	0.0541530	0.0000000	0.0000000
Alternative -08	0.0584206	0.0000000	0.0541530	0.0000000	0.3779645
Alternative -09	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -10	0.9347300	0.1360828	3.4657943	0.0000000	0.0000000
Alternative -11	0.2336825	0.1360828	0.2166121	0.0000000	0.0000000
Alternative -12	0.0584206	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -13	0.0584206	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -14	0.0584206	0.5443311	0.0000000	0.0000000	0.0000000
Alternative -15	0.2336825	0.0000000	0.0000000	0.4082483	0.0000000
Alternative -16	0.0584206	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -17	0.5257856	0.0000000	0.0000000	0.0000000	0.3779645
Alternative -18	0.0584206	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -19	0.0584206	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -20	0.0000000	0.1360828	0.0541530	0.0000000	0.0000000
Alternative -21	0.0000000	0.1360828	0.0000000	0.0000000	0.0000000
Alternative -22	0.0000000	0.1360828	0.0000000	0.0000000	0.0000000
Alternative -23	0.0000000	0.0000000	0.0000000	0.4082483	0.0000000

Now, using Eq. (3) the weighted normalized decision matrix is made from the values of Table 6. Table 6also shows the determined the positive ideal (A+) and negative ideal solutions (A-) using Eq. (4) and Eq. (5).

Table 7 Weighted normalized matrix

S No.	Near Miss	Fire Incident	Minor Accident	Major Accident	Fatal Accidents
Alternative -01	0.2862611	0.1837117	0.6931589	0.0000000	0.4535574
Alternative -02	0.0058421	0.0000000	0.0108306	0.0000000	0.0000000
Alternative -03	0.9873085	0.7348469	2.1227990	0.4082483	0.0000000
Alternative -04	0.1460516	0.0000000	0.0433224	0.0000000	0.0000000
Alternative -05	0.0000000	0.0000000	0.0433224	0.0000000	0.1133893
Alternative -06	0.0525786	0.0000000	0.0108306	0.0000000	0.0000000
Alternative -07	0.0000000	0.0000000	0.0108306	0.0000000	0.0000000
Alternative -08	0.0058421	0.0000000	0.0108306	0.0000000	0.1133893
Alternative -09	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -10	0.0934730	0.0204124	0.6931589	0.0000000	0.0000000
Alternative -11	0.0233682	0.0204124	0.0433224	0.0000000	0.0000000
Alternative -12	0.0058421	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -13	0.0058421	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -14	0.0058421	0.0816497	0.0000000	0.0000000	0.0000000
Alternative -15	0.0233682	0.0000000	0.0000000	0.1020621	0.0000000
Alternative -16	0.0058421	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -17	0.0525786	0.0000000	0.0000000	0.0000000	0.1133893
Alternative -18	0.0058421	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -19	0.0058421	0.0000000	0.0000000	0.0000000	0.0000000
Alternative -20	0.0000000	0.0204124	0.0108306	0.0000000	0.0000000
Alternative -21	0.0000000	0.0204124	0.0000000	0.0000000	0.0000000
Alternative -22	0.0000000	0.0204124	0.0000000	0.0000000	0.0000000
Alternative -23	0.0000000	0.0000000	0.0000000	0.1020621	0.0000000
V+	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
V-	0.9873085	0.7348469	2.1227990	0.4082483	0.4535574

The next step involved the determination of distance of each alternative from the positive ideal solution (PIS) A^+, d_i^+ and Negative ideal solution (NIS) A^-, d_i^- using Eq (6) and Eq.(7) as shown in Table 8. Table 8 also shows the relative closeness (R_i)from the ideal solution for each alternative using Eq.(8). Then on the basis of R_i values, the alternatives are ranked.

Table 8: Ranking of alternatives

S No.	d_i^+	d_i^-	R_i	Rank	Mixed Rank
Alternative -01	0.8954769	1.7337114	0.659409	2	2
Alternative -02	0.0123058	2.5171547	0.995135	16	15
Alternative -03	2.4875129	0.4535574	0.154215	1	1
Alternative -04	0.1523414	2.4380970	0.941191	4	4
Alternative -05	0.1213836	2.4741427	0.953234	6	6
Alternative -06	0.0536825	2.4993022	0.978973	12	12
Alternative -07	0.0108306	2.5194384	0.99572	17	16
Alternative -08	0.1140551	2.4992135	0.956355	7	7
Alternative -09	0.0000000	2.5285242	1	23	18
Alternative -10	0.6997307	1.9301841	0.733934	3	3
Alternative -11	0.0532877	2.4771357	0.978941	11	11
Alternative -12	0.0058421	2.5262488	0.997693	18	17
Alternative -13	0.0058421	2.5262488	0.997693	19	17
Alternative -14	0.0818584	2.5037172	0.96834	10	10
Alternative -15	0.1047031	2.5049792	0.959879	8	8
Alternative -16	0.0058421	2.5262488	0.997693	20	17
Alternative -17	0.1249866	2.4904571	0.952212	5	5
Alternative -18	0.0058421	2.5262488	0.997693	21	17
Alternative -19	0.0058421	2.5262488	0.997693	22	17
Alternative -20	0.0231078	2.5135605	0.990891	13	13
Alternative -21	0.0204124	2.5226675	0.991973	14	14
Alternative -22	0.0204124	2.5226675	0.991973	15	14
Alternative -23	0.1020621	2.5140641	0.960987	9	9

Table 9 Ranking of Companies using TOPSIS

Alternative	Company	Mixed Rank
Alternative -03	M/S COMPANY 3	1
Alternative -01	M/S COMPANY 1	2
Alternative -10	M/S COMPANY 10	3
Alternative -04	M/S COMPANY 4	4
Alternative -17	M/S COMPANY 17	5
Alternative -05	M/S COMPANY 5	6
Alternative -08	M/S COMPANY 8	7
Alternative -15	M/S COMPANY 15	8
Alternative -23	M/S COMPANY 23	9
Alternative -14	M/S COMPANY 14	10
Alternative -11	M/S COMPANY 11	11
Alternative -06	M/S COMPANY 6	12
Alternative -20	M/S COMPANY 20	13
Alternative -21	M/S COMPANY 21	14
Alternative -22	M/S COMPANY 22	14
Alternative -02	M/S COMPANY 2	15
Alternative -07	M/S COMPANY 7	16
Alternative -12	M/S COMPANY 12	17
Alternative -13	M/S COMPANY 13	17
Alternative -16	M/S COMPANY 16	17
Alternative -18	M/S COMPANY 18	17
Alternative -19	M/S COMPANY 19	17
Alternative -09	M/S COMPANY 9	18

Table 9 shows the ranking of companies based on their accident, incident and near miss record in descending order. The significance of the ranking obtained in the above table is to determine the company with past accident record requiring immediate intervention through proper training of the workers. This prioritization of companies for work specific training will help to identify the company workers who need more training in order to prevent any accident, incident and near miss in the near future. It can be clearly observed from Table 7 and Table 8 that M/S Company 3, M/S Company 1 and M/S Company 10 have significantly contributed in the accident, incident and near-miss record in the past four years (2017-20). Therefore, more emphasis should be given to the training provided to the workers of these companies. Whereas, the contribution of M/S Company 12, M/S Company 13, M/S Company 16, M/S Company 18, M/S Company 19 and M/S Company 9 in the accident, incident and near-miss record in the past four years (2017-20) is very less, therefore there is no need to give more emphasis on specific training to the workers of these companies. Periodic general safety training along with induction training should be suffice the task.

5. CONCLUSIONS

The research attempts to determine the company which should be kept in the priority to provide safety training in construction of thermal power station. The Fuzzy TOPSIS approach used to rank the companies on the basis of safety training needs shows that contractual workers of few specific companies have significantly contributed in the accident, incident and near-miss record in the past four years (2017-20). The ranking approach used in the research for identification of companies that need immediate work specific training can also be used in different application to set the priority of work.

The future work in the research may involve the development of a system in place wherein the feedback is

acquired periodically from the trainees which may be assessed to determine the effectiveness of the safety training programs and adjust the design of the training programs wherever necessary.

6. REFERNECES

[1] A. Lahiri, "Skilling crisis in India and the way forward," AFT Media, 2021. https://autofintechs.com/skilling-crisis-in-india-and-the-way-forward/.
[2] R. A. Noe, Employee Training & Development. McGraw-Hill Education, 2016.
[3] K. R. Andrews, "THE EFFECTIVENESS OF UNIVERSITY MANAGEMENT DEVELOPMENT PROGRAMS.," 1966.
[4] M. C. Agarwal and M. V. Ananthakrishnan, "Training Aids and Facilities in Indian Industries," Indian J. Train. Dev., p. P.171-173., 1980.
[5] U. Pagey, "Training for Better Organisational performance," Indian J. Train. Dev., p. P.156-157, 1981.
[6] U. Kohli, "A New Approach to Training and Development in Developing Countries," Indian J. Train. Dev., pp. 3–10, 1997.
[7] R. A. Noe and N. Schmitt, "The influence of trainee attitudes on training effectiveness: Test of a model," Pers. Psychol., vol. 39, no. 3, pp. 497–523, 1986.
[8] M. A. Vojtecky and M. F. Schmitz, "Program evaluation and health and safety training," J. Safety Res., vol. 17, no. 2, pp. 57–63, 1986.
[9] H. H. Cohen and R. C. Jensen, "Measuring the effectiveness of an industrial lift truck safety training program," J. Safety Res., vol. 15, no. 3, pp. 125–135, 1984.
[10] T. M. Lippin, A. Eckman, K. R. Calkin, and T. H. McQuiston, "Empowerment-based health and safety training: Evidence of workplace change from four industrial sectors," Am. J. Ind. Med., vol. 38, no. 6, pp. 697–706, 2000.
[11] M. J. Colligan, A. B. Cohen, F. Julian, and M. R, "The role of training in promoting workplace safety and health," Psychol. Work. safety, Am. Psychol. Assoc., vol. 11, p. pp-223-248, 2004.
[12] L. S. Robson et al., "A systematic review of the effectiveness of occupational health and safety training," Scand. J. Work. Environ. Health, pp. 193–208, 2012.
[13] M. J. Burke, S. A. Sarpy, K. Smith-Crowe, S. Chan-Serafin, R. O. Salvador, and G. Islam, "Relative effectiveness of worker safety and health training methods," Am. J. Public Health, vol. 96, no. 2, pp. 315–324, 2006.
[14] L. Robson et al., "A systematic review of the effectiveness of training & education for the protection of workers," Toronto Inst. Work Heal., vol. 2127, 2010.
[15] M. J. Burke, R. O. Salvador, K. Smith-Crowe, S. Chan-Serafin, A. Smith, and S. Sonesh, "The dread factor: how hazards and safety training influence learning and performance.," J. Appl. Psychol., vol. 96, no. 1, p. 46, 2011.
[16] R. F. Baumeister, K. D. Vohs, C. Nathan DeWall, and L. Zhang, "How emotion shapes behavior: Feedback, anticipation, and reflection, rather than direct causation," Personal. Soc. Psychol. Rev., vol. 11, no. 2, pp. 167–203, 2007.
[17] J. S. Beer, E. A. Heerey, D. Keltner, D. Scabini, and R. T. Knight, "The regulatory function of self-conscious emotion: insights from patients with orbitofrontal damage.," J. Pers. Soc. Psychol., vol. 85, no. 4, p. 594, 2003.
[18] P. Slovic and E. Peters, "Risk perception and affect," Curr. Dir. Psychol. Sci., vol. 15, no. 6, pp. 322–325, 2006.
[19] K. Sweeny and J. A. Shepperd, "Do people brace sensibly? Risk judgments and event likelihood," Personal. Soc. Psychol. Bull., vol. 33, no. 8, pp. 1064–1075, 2007.
[20] D. E. Warren and K. Smith-Crowe, "Deciding what's right: The role of external sanctions and embarrassment in shaping moral judgments in the workplace," Res. Organ. Behav., vol. 28, pp. 81–105, 2008.
[21] J. R. Wilkins, "Construction workers' perceptions of health and safety training programmes," Constr. Manag. Econ., vol. 29, no. 10, pp. 1017–1026, 2

Annexure-I: Questionnaire for the employees

1. Name :
2. Age

Below 20	(____)	31-50	(____)
21-30	(____)	Above 50	(____)

3. Gender

Male	(____)	Female	(____)

4. Marital status

Married	(____)	Unmarried	(__)

5. Educational Qualification

Secondary	(____)	Graduation	(____)
Post-graduation	(____)	Others	(____)

6. Nature of Job :
7. Experience (in years)

1-5	(____)	16-20	(____)
6-10	(____)	21-25	(____)
11-15	(____)	Above 25	(____)

8. Designation

Supervisor	(____)	Contract worker	(____)
Worker	(____)	Sub-contract worker	(____)

9. Preferred duration of training.

Less than 10 Days	(____)	4 week	(____)
3 week	(____)	5 week	(____)

10. Usefulness of training

Highly useful	(____)
useful	(____)
satisfactory	(____)

11. Is training associated with promotion?

Yes	(____)	No	(____)

12. Let's say you've done 5 training programs so far, how many were useful?

1	(____)	4	(____)
2	(____)	5	(____)
3	(____)		

13. What type of training do you like

family related	(____)	personality related	(____)
work related	(____)	General safety related	(____)

14. Answer the below questions

		Yes	No
(i)	Do you believe that training helps to acquire new skills	(____)	(____)
(ii)	Do you believe that training helps to raise awareness	(____)	(____)
(iii)	Do you believe that training helps to enhance organizational culture	(____)	(____)
(iv)	Do you believe that training helps to increase creativity?	(____)	(____)
(v)	Do you believe that training helps to improve decision making skills	(____)	(____)
(vi)	Do you believe that training helps to improve technical skills	(____)	(____)
(vii)	Do you believe that training helps to develop and manage oneself	(____)	(____)

		Excellent	Very Good	Good	Fair	Poor
15.	Communication Skills Effectiveness Happened Through Training Program	(____)	(____)	(____)	(____)	(____)
16.	There is an improvement in the level of confidence through the training program	(____)	(____)	(____)	(____)	(____)
17.	Technical skill development through training program has been effective	(____)	(____)	(____)	(____)	(____)
18.	Decision making skills have been effectively achieved through the training program	(____)	(____)	(____)	(____)	(____)
19.	Effectiveness of safety awareness through training program	(____)	(____)	(____)	(____)	(____)
20.	Interpersonal skills and team building effectiveness through training program	(____)	(____)	(____)	(____)	(____)
21.	Ways to assess training needs in your organization	(____)	(____)	(____)	(____)	(____)
22.	The importance given to employee training and development in your organization	(____)	(____)	(____)	(____)	(____)
23.	Methods of training employees in your organization	(____)	(____)	(____)	(____)	(____)
24.	Facilities for conducting training programs available in your organization	(____)	(____)	(____)	(____)	(____)